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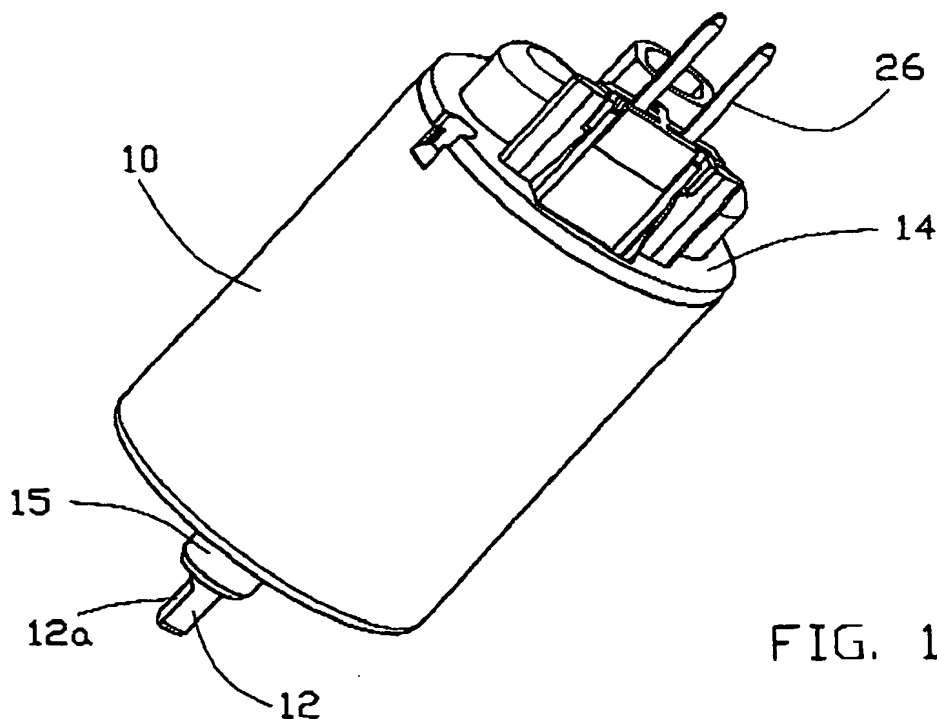
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(54) **Brushless D.C. motor**

(57) The brushless direct current motor comprises a housing 10, a stator 13 and a rotor 11 within the housing, windings on the stator, sensors for sensing the position of the rotor relative to the stator and electronic circuitry for switching the current in the windings in re-

sponse to outputs from the sensors to cause the rotor to rotate relative to the stator. The sensors and at least a part of the electronic circuitry are encapsulated in an electrically insulating and fuel resistant material in a container within the housing.



**FIG. 1**

## Description

[0001] This invention relates to a brushless direct current motor and more particularly but not exclusively to such a motor for use in conjunction with a fuel pump.

[0002] Conventional permanent magnet direct current (PMDC) motors are traditionally designed with relatively inexpensive commutating parts comprising a commutator and a brush/leaf system. For many specific applications these brush-type motors will keep their importance, especially at the lower end of the applications range.

[0003] On the other hand, the dependence upon electronic control systems is growing, from varied car applications at different voltages to professional power tools. Meanwhile, parameters such as long life, efficiency, reliability, low electro-magnetic interference and noise are becoming of greater importance.

[0004] Brushless direct current (BLDC) motor technology makes it possible to achieve these requirements. Problems associated with brushes are eliminated. Advances in MOSFET and surface-mount technology lead to lower voltage drop (with a reduction of heat sinking), to smaller required space and to a tendency of price reduction.

[0005] According to a first aspect of the invention there is provided a brushless direct current motor comprising a housing, a stator and a rotor within the housing, windings on the stator or the rotor, sensors for sensing the position of the rotor relative to the stator and electronic circuitry for switching the current in the windings in response to outputs from the sensors to cause the rotor to rotate relative to the stator, the sensors and at least a part of the electronic circuitry being encapsulated in an electrically insulating material in a container within the housing.

[0006] Preferred and/or optional features of the second aspect of the invention are set forth in claims 2 to 8 inclusive.

[0007] According to a second aspect of the invention there is provided a brushless direct current motor comprising a wound stator and a permanent magnet rotor, the rotor having a laminated core and being overmoulded with magnetisable material magnetised subsequent to moulding.

[0008] Preferred and/or optional features of the second aspect of the invention are set forth in claims 9 to 14 inclusive.

[0009] Preferred and/or optional features of both aspects of the invention are set forth in claims 15 to 17 inclusive.

[0010] The invention will now be more particularly described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a perspective view of one embodiment of a brushless direct current motor according to the present invention,

Figure 2 is a cut away view of the motor shown in Figure 1,

Figure 3 is a perspective exploded view of the container for containing for electronic circuitry of the motor shown in Figures 1 and 2,

Figure 4 is a perspective view of the container of Figure 3 mounted on the stator and containing the electronic circuitry.

Figure 5 is a perspective underneath view of the container shown in Figure 3,

Figure 6 is a perspective view of a front insulator of the motor,

Figure 7 is a perspective view of the rotor of the motor,

Figure 8 is a partly broken away view of the rotor shown in Figure 7,

Figure 9 is a plan view showing the rotor and stator laminations of the motor,

Figure 10 is a plan view of a second embodiment of a modified rotor lamination,

Figure 11 is a plan view of another modified rotor lamination,

Figure 12 is a perspective fragmentary view of an alternative stator, and

Figure 13 is a perspective view of the stator shown in Figure 11 with the flux pieces added.

[0011] Referring now to the drawings, the brushless direct current motor shown therein comprises a deep drawn outer housing 10, a rotor 11 including a shaft 12 having a flat 12a at the end projecting from the closed end of the housing 10, a wound stator 13 surrounding the rotor 11, an end cap 14 closing the open end of the housing 10, and a container 16 within the housing 10 for sensors and electronic circuitry. The wound stator 13 comprises a stator winding 19 wound about a stack of stator laminations 30.

[0012] The motor has an overall appearance similar to that of a conventional permanent magnet direct current motor having commutating parts comprising a commutator and brush/leaf system. The motor has particular application as a fuel pump motor, but also has other uses.

[0013] Referring now to Figures 3 to 5, the container 16 comprises a cylindrical bowl 17 having an integral sleeve 18 upstanding from the base of the bowl. The container is typically formed of Polyacetal (POM) and

contains sensors, typically in the form of Hall-effect sensors, for sensing the position of the rotor 11 relative to the stator 13 and electronic circuitry mounted on an annular printed circuit board 20 which fits over the upstanding sleeve 18. Ideally the Hall-effect sensors lie flat on the printed circuit board 20. This is advantageous as compared to conventional "standing" hall sensors because it is easier to assemble and more reliable against fuel and vibrations after full encapsulation. Also, it allows a reduction in distance between the sensors and the planar top surface of the permanent magnet rotor. The circuitry switches the current in the stator windings in known manner in response to outputs from the sensors to cause the rotor to rotate relative to the stator. The sensors and electronic circuitry are then encapsulated in electrically insulating material, typically epoxy resin, which fills or substantially fills the container 16. The sleeve 18 is dimensioned such as to allow the rotor shaft 12 to extend therethrough and to allow fuel from the fuel pump to flow therethrough.

**[0014]** The sensors and most of the electronic components, including all electrically conductive parts thereof, are fully encapsulated. Only such parts as, for example, electrical terminals and/or large capacitors will not be encapsulated fully.

**[0015]** As shown in Figure 5, the underside of the base of the bowl 17 has four insulation displacement connectors 21 for direct connection to windings of the stator 13. The container 16 and its contents can be pre-assembled allowing it to be "plugged" into the motor.

**[0016]** The thermal conductivity of the encapsulating material may not be too important because of the cooling effect of fuel passing through the sleeve 18.

**[0017]** Figure 6 shows in detail a front insulator 22 which is placed on the stator and which has the same number of slots 23 (four in this example) for receiving the stator windings and the insulation displacement connections 21 on the container 16.

**[0018]** Instead of mounting the sensors and the electronic circuitry on a printed circuit board, the internal bottom surface of the container 16 could have an electrically conductive pattern imprinted thereon. This can take the form of a heat-press foil applied with a heat-press stamp. All electronic components can then be automatically assembled on the bowl's inner surface and subsequently encapsulated. Another advantage of this technique is a further reduction in the distance between hall sensors and the planar top surface of rotor's magnet resulting in increased magnet field strength for position detection.

**[0019]** The motor also has a rear insulator 24 similar to but not identical to the front insulator 22.

**[0020]** The end cap 14 is connected to the housing 10 such as by crimping the rim of the housing 10 on the end cap at e.g. two positions. This end cap 14 supports or defines a bearing for the rotor shaft 12 and also includes integral features needed for a customer's fuel pump. A termination 26 is provided on the end cap 14

for connection to an external supply.

**[0021]** A sleeve 15 is provided at the other end of the motor. The sleeve 15 is typically formed of Polyphenylsulfide (PPS). This material has a high heat dimensional stability, low elongation and extremely good resistance against all kinds of aggressive fuels. The sleeve 15 supports or defines a bearing for the rotor shaft 12 and is also for attachment to a customer's fuel pump by press fitting into a hole in the fuel pump housing. Conventionally, the sleeve 15 has been part of the pump housing. It is now a part of the motor. This is advantageous as it serves the dual purpose of supporting or defining a bearing for the rotor shaft 12 and as a connecting/aligning element for the pump housing and allows the motor to be fully tested before supply to a customer.

**[0022]** The use of a brushless direct current motor as opposed to a conventional commutator motor makes a radial and axial reduction of motor dimensions possible.

**[0023]** Referring now to Figures 7 to 11, the rotor comprises a rotor shaft 12 and a laminated core 27 overmoulded with material 33 magnetised subsequent to moulding.

**[0024]** The laminated core 27 comprises a plurality of rotor laminations 29. As shown in Figure 9, these laminations are stamped from sheet metal and maybe stamped at the same time as stator laminations 30 to save the cost of a separate core. The rotor laminations 29 have three equi-angularly spaced, radially inwardly extending, slots 31 and a central aperture 32 for mounting the laminations on the rotor shaft 12. A stack of these laminations 30 are overmoulded with magnetisable material 33, typically thermoplastic bonded NdFeB compound and this (isotropic) material 33 is magnetised (as shown in Figure 7) subsequent to moulding. The overmoulding may also include an integral ring 34 which can be charged like an encoding disc to give a higher magnetic field strength in the axial direction (necessary for the Hall sensors).

**[0025]** A rotor formed in this manner does not require any glue and is simple to assemble. Also no balancing is needed. The moulding material 33 also fills the slots 31.

**[0026]** Figure 10 shows an alternative rotor lamination having six apertures 35 therein. These apertures 35 are equi-angularly spaced and three of the apertures are larger than the others. This reduces the weight of the rotor core 27 although, preferably, in order to avoid fuel pump rotor punch losses (i.e. losses due to turbulences of rotor in the fluid) the end laminations preferably have no such apertures 35.

**[0027]** Figure 11 shows yet a further rotor lamination having no slots 31 but an uneven, knurled peripheral surface and six apertures 35' of equal dimensions.

**[0028]** The stator laminations 30 shown in Figure 9 are stamped at the same as the rotor laminations and comprise an outer ring 36, four equi-angularly spaced, radially inwardly extending pole pieces 37 around which

windings (not shown) are wound and four flux pieces between the pole pieces 37. A stack of these laminations is difficult to wind because of the small gaps between the pole shoes 37 and the flux pieces 38. Also, external coil winding around pole pieces with subsequent insertion onto outer ring is not recommended for small-sized motors.

**[0029]** In one aspect of the invention, and as shown in Figures 12 and 13, an alternative stator 13', has an outer ring 36', a plurality of angularly spaced pole pieces 37' extending radially inwardly from the outer ring 36' and a plurality of flux pieces 38' between the pole pieces 37'. The flux pieces 38' are separate from the ring 36' and pole pieces 37' and are slidable into slots 39 defined by the outer ring 36' subsequent to winding of the pole pieces 37'. This simplifies the winding process and allows the flux pieces 38 to be optimally shaped.

**[0030]** The ring 36' and pole pieces 37' are integrally formed and could be formed of stamped laminations secured together such as by laser welding/package punching or more preferably are formed in a unitary construction by moulding soft-magnetic sintered material.

**[0031]** The embodiments described above are given by way of example only and various modifications will be apparent to persons skilled in the art without departing from the scope of the invention as defined in the appended claims. For example, the rotor could surround the stator, more particularly when used as fan motors or storage drives.

## Claims

1. A brushless direct current motor comprising a housing (10), a stator (13) and a rotor (11) within the housing, windings on the stator, sensors for sensing the position of the rotor relative to the stator and electronic circuitry for switching the current in the windings in response to outputs from the sensors to cause the rotor to rotate relative to the stator, the sensors and at least a part of the electronic circuitry being encapsulated in an electrically insulating and fuel resistant material in a container (16) within the housing.
2. A motor as claimed in claim 1, wherein the sensors are Hall-effect sensors laid flat on or adjacent to the end of the container (16) nearest to the rotor (11).
3. A motor as claimed in claim 1 or claim 2, wherein all electrically conducting parts of the electronic circuitry are encapsulated in the electrically insulating and fuel resistant material.
4. A motor as claimed in any one of claims 1 to 3, wherein the container (16) has an internal sleeve (18) through which a shaft (12) of the rotor extends and through which fuel from a fuel pump can flow.
5. A motor as claimed in any one of claims 1 to 4, wherein the sensors and electronic circuitry are mounted on a printed circuit board (20) in the container (16).
6. A motor as claimed in any one of claims 1 to 5, wherein the sensors and electronic components of the circuitry are electrically connected by an electrically conductive pattern imprinted on an internal surface of the container.
7. A motor as claimed in any one of claims 1 to 6, wherein the container (16) has external insulation displacement connections (21) for direct connection to the windings.
8. A motor as claimed in any one of claims 1 to 7, wherein the container (16) and its contents are pre-assembled.
9. A brushless direct current motor comprising a wound stator (13) and a permanent magnet rotor (11), the rotor (11) having a laminated core (27) and being overmoulded with material (33) magnetised subsequent to moulding.
10. A motor as claimed in claim 9, wherein the core of the rotor has a plurality of angularly spaced slots (31) extending inwardly from its outer peripheral surface and the slots are filled with said material (33).
11. A motor as claimed in claim 9 or claim 10, wherein at least some of the laminations (29) have a plurality of spaced apertures (35) therein.
12. A motor as claimed in any one of claims 9 to 11, wherein the outer peripheral surfaces of the laminations (29) are uneven.
13. A motor as claimed in claim 12, wherein the outer peripheral surfaces of the laminations (29) are knurled.
14. A motor as claimed in any one of claims 9 to 13, further comprising sensors for sensing the position of the rotor relative to the stator and electronic circuitry for switching the current in the stator windings in response to outputs from the sensors to cause the rotor to rotate relative to the stator.
15. A motor as claimed in any one of claims 1 to 14, wherein the stator (13) surrounds the rotor (11) and has an outer ring (36), a plurality of angularly spaced pole pieces (37) extending inwardly from the outer ring and a plurality of flux pieces (38) between the pole pieces, the flux pieces having been inserted after applying windings to the pole pieces.

16. A motor as claimed in claim 15, wherein the outer ring (36) defines a plurality of slots (39) on its inner surface for slidably receiving a flux piece (38') between each adjacent pair of wound pole pieces (37').

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17. A motor as claimed in any one of claims 1 to 16, further comprising a sleeve (15) at one end of the motor for supporting or defining a bearing for the rotor and for attachment to a fuel pump.

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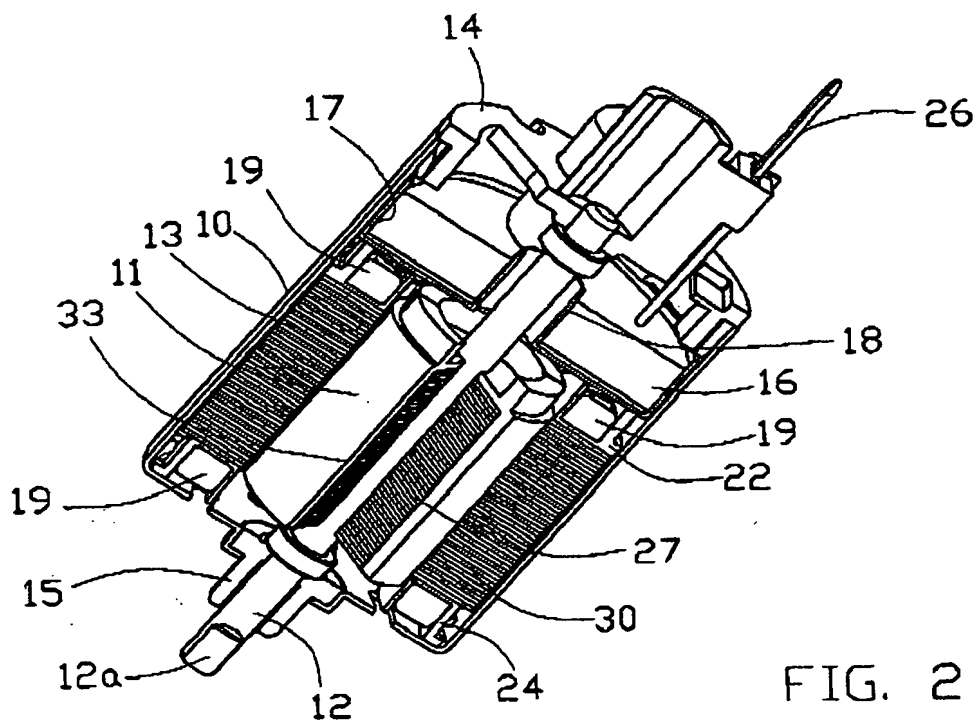
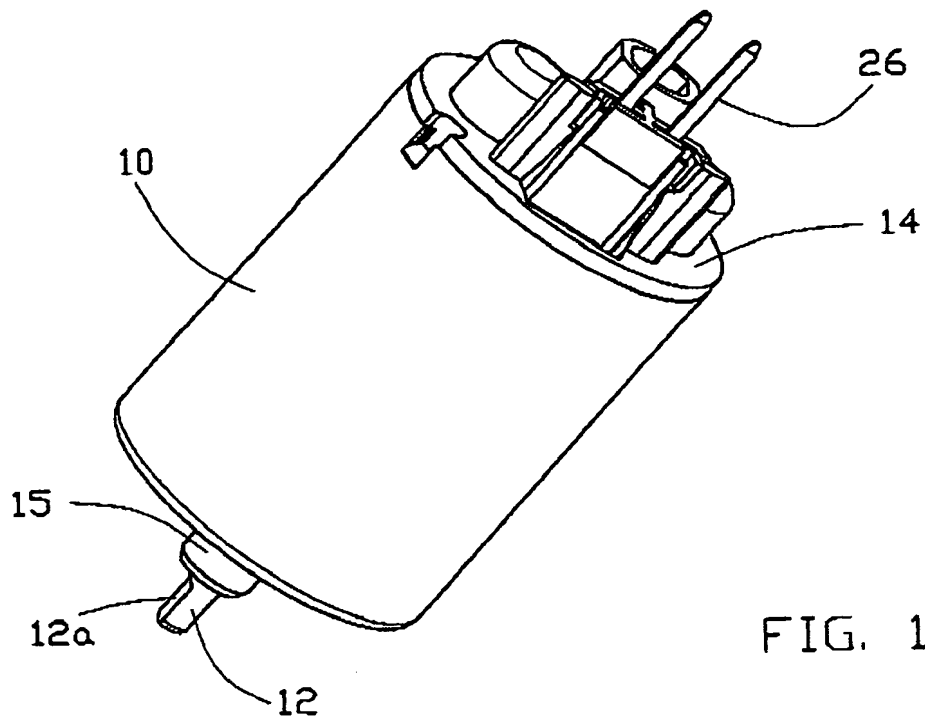
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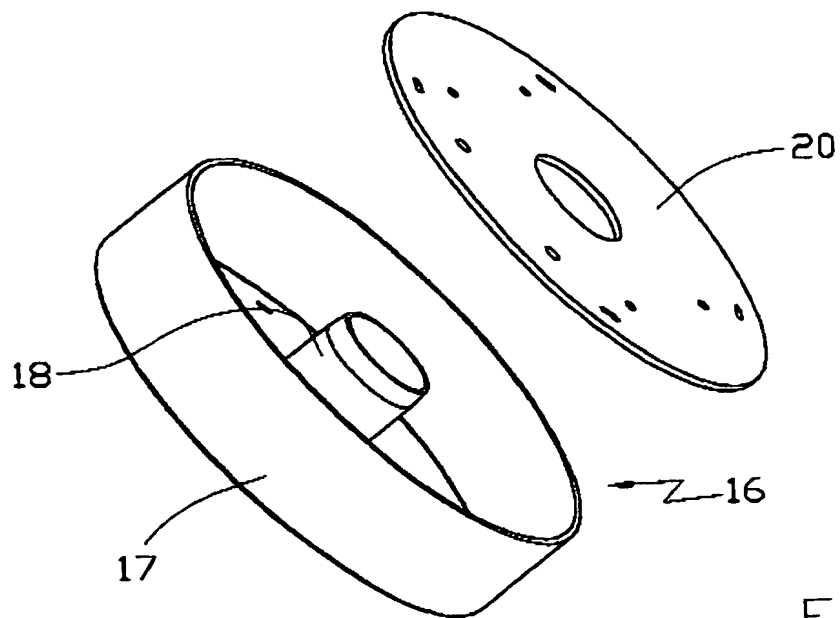


FIG. 3

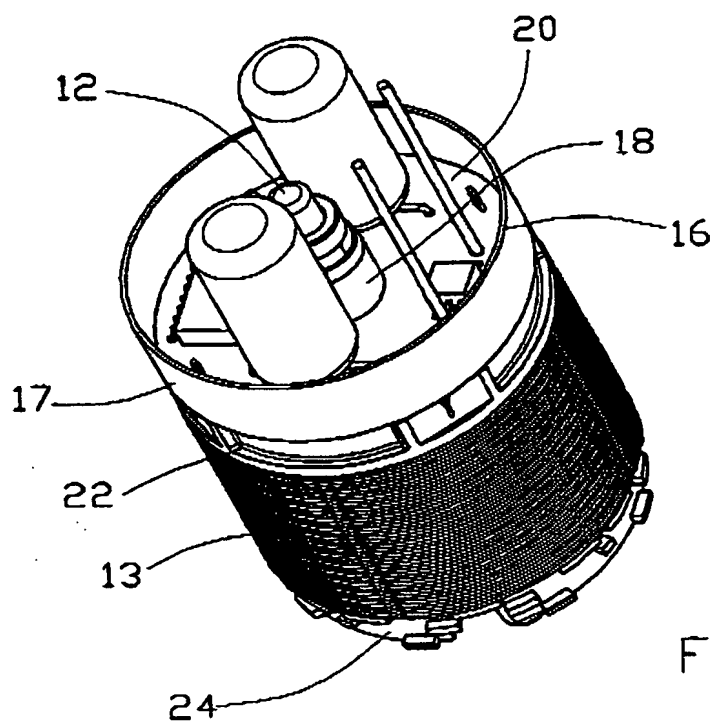


FIG. 4

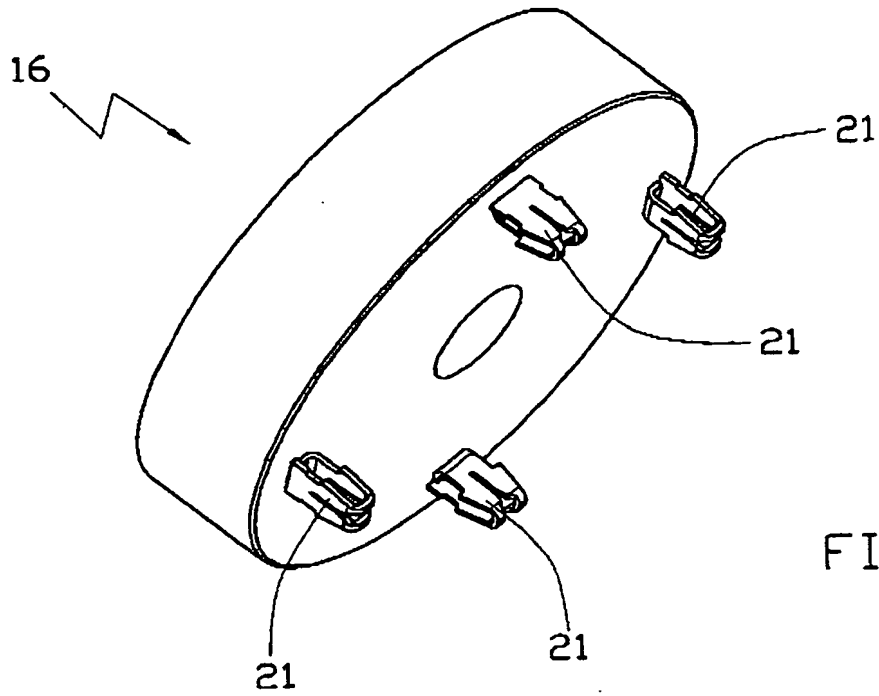


FIG. 5

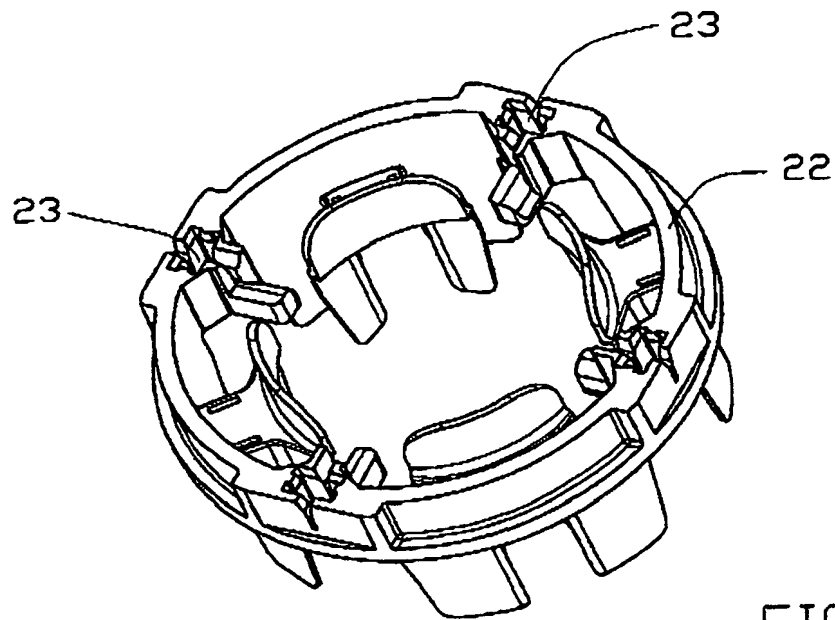


FIG. 6



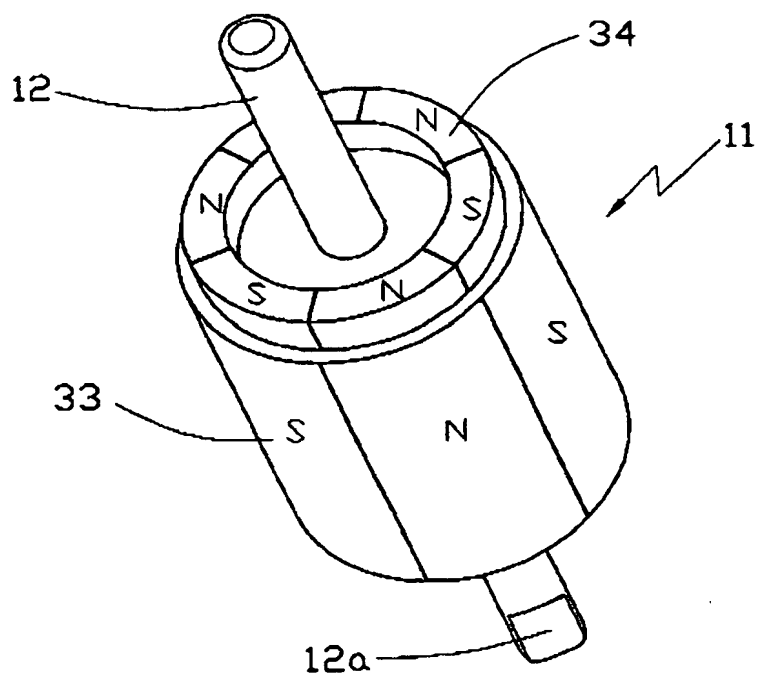


FIG. 7

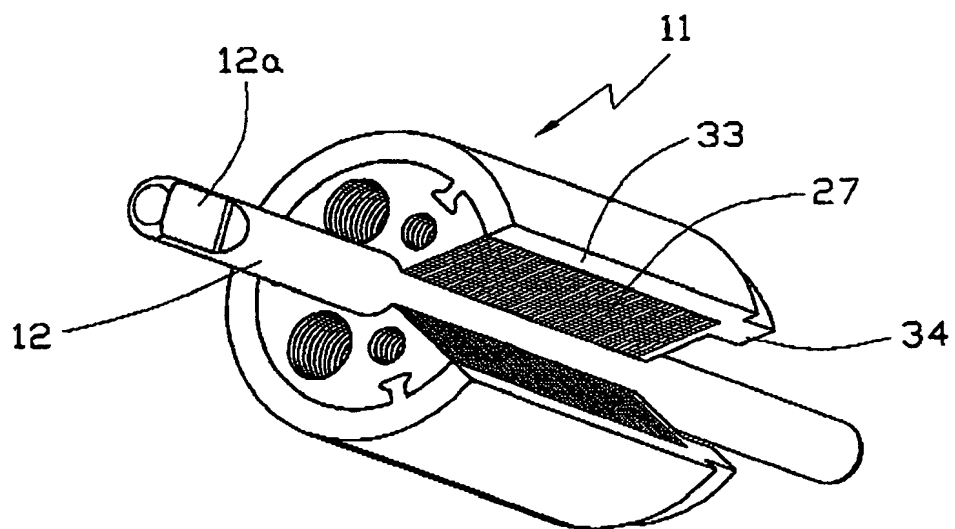


FIG. 8

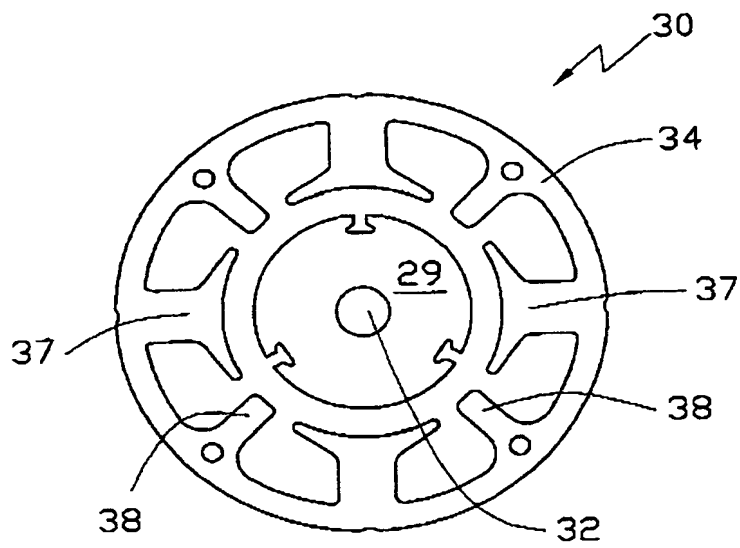


FIG. 9

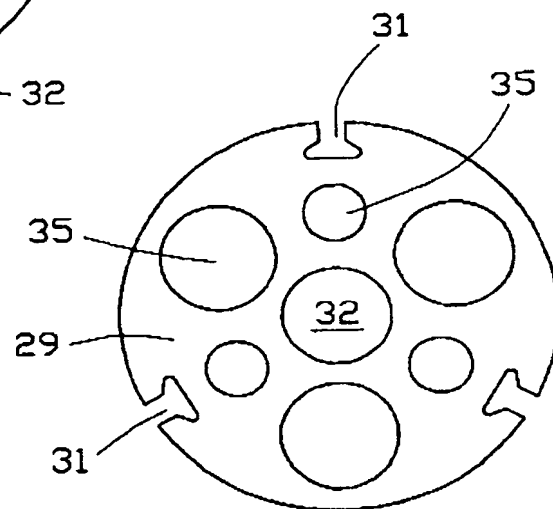


FIG. 10

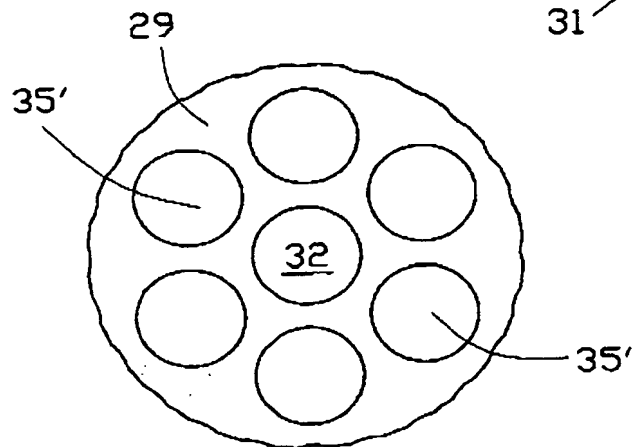


FIG. 11

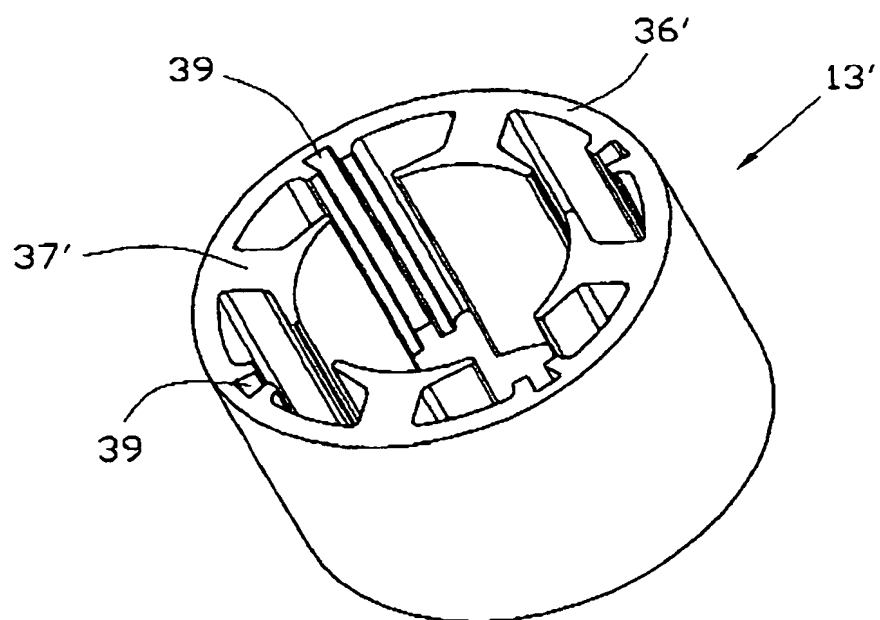


FIG. 12

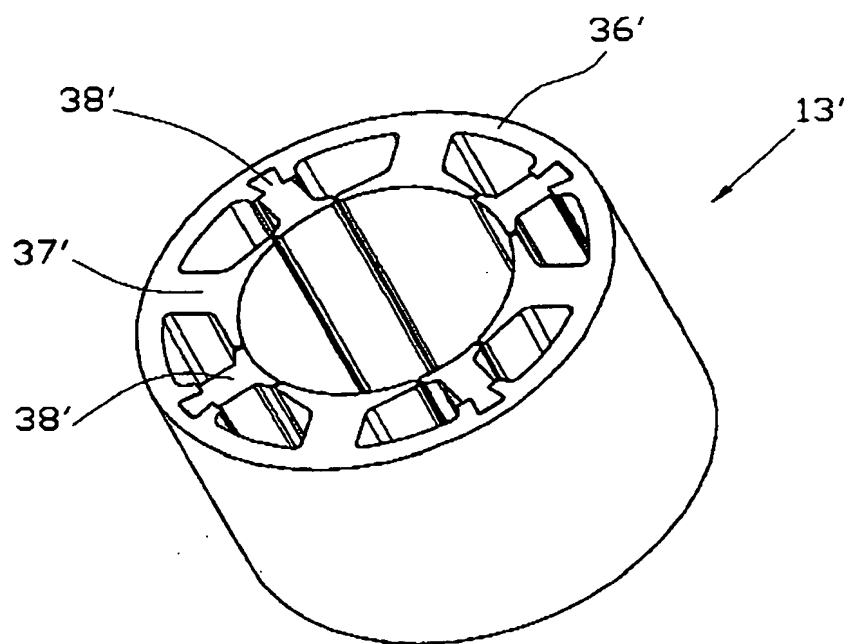


FIG. 13

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